Green Sorbent Media for Mitigation of Urban Road Runoff Pollution

Testing of Wood Mulch Coated with Water Treatment Residuals for Mitigation of Dissolved Metals and Phosphorus

Kirk Barrett, PhD, PE, Manhattan College
Dibyendu Sarkar, PhD, PG, Stevens Institute of Technology
Yang Deng, PhD, PE, Montclair State University

Problem

- Urban runoff pollutants (TSS, metals, nutrients, pathogens, salts, …)

Problem

- Urban stormwater management

Grey Infrastructure:
Stormwater = Waste

vs.

Green Infrastructure:
Stormwater = Resource

Green Infrastructure (GI) approaches to cleaning and reducing urban stormwater runoff

- Infiltration systems
- Detention systems
- Retention systems
- Constructed wetlands
- Vegetated systems
- Filtration systems

Limitations to GI stormwater treatment practices

- Uncertain Phosphorus (P) removal (sometimes P even increased in the effluent).

- Accumulation of metals in the soil
  - can exceed non-toxic limits
  - replacement of soil is costly

Goal, Objective & Hypotheses

- **Long-term Goal**
  - Develop an effective, low-cost, and simple technology for stormwater treatment.
- **Immediate Objective**
  - Evaluate water treatment residual (WTR)-coated wood mulch for adsorption of dissolved metals and P in urban stormwater .
- **Hypotheses**
  - WTRs are capable of irreversibly adsorbing heavy metals and P in water.
  - Leaching of undesirable chemicals from original and used WTRs is minimal.

What are Water Treatment Residuals (WTRs)?

- Aluminum-based WTRs at Water Treatment Plant (Bridgewater, NJ)

Water Treatment Residuals (WTRs)

- By-product of municipal drinking water treatment coagulation and flocculation.
- Primarily amorphous masses of aluminum and iron hydroxides as well as some humic substances and activated carbon.
- More than 2 million tons generated each year in US, most of which are landfilled or incinerated.
- Can often be obtained for little or no cost.
- Using WTRs for stormwater treatment represents a beneficial reuse of a waste.
- Co-PI, Dr Sarkar has researched WTRs as sorbents for removal of soil and water pollutants for over a decade, publishing 40+ peer-reviewed articles on the topic.

Water Treatment Residuals (WTRs)

- WTRs require minimal processing to be used as an adsorbent – sieving and grinding to achieve large specific surface area.
- But, hydraulic properties are poor.
- **Solution**: apply a coating of WTRs to wood mulch to improve hydraulic conductivity.
- "Garden variety" cedar wood mulch was used.
- Commercial "mulch glue" was used to bind WTRs to mulch at a mass ratio of 1 to 3.

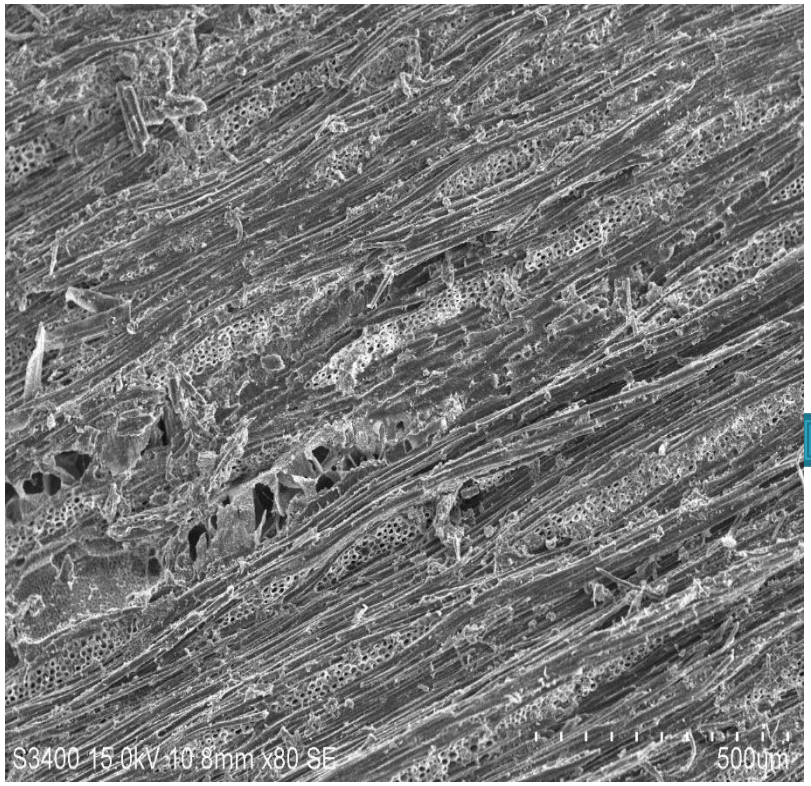
WTR-coated wood mulch

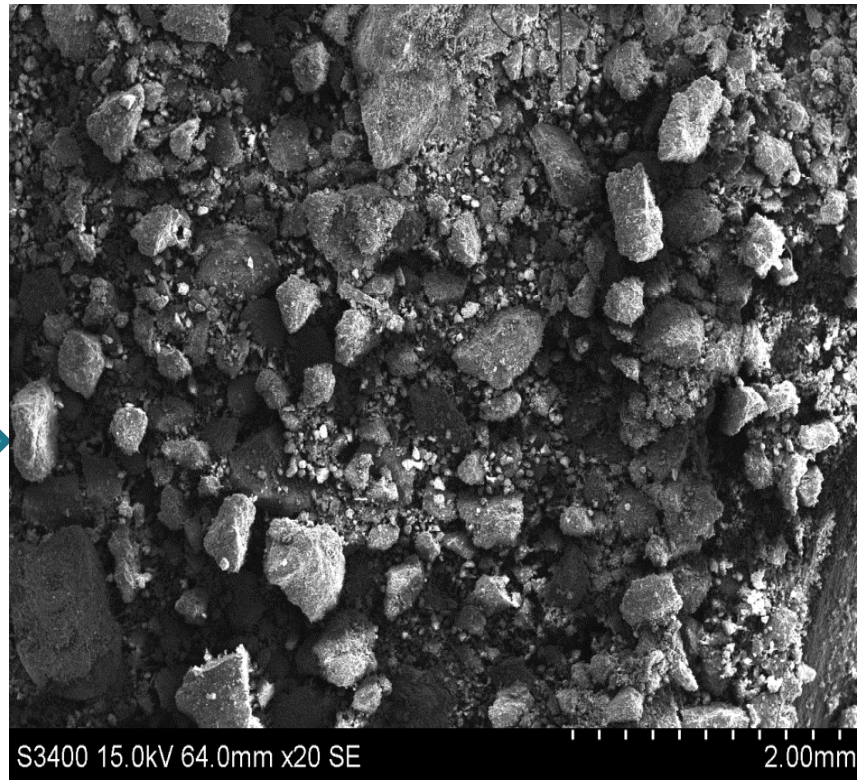
Mulch + WTR

Uncoated mulch

WTR-coated mulch

Micrographic images of mulch surface

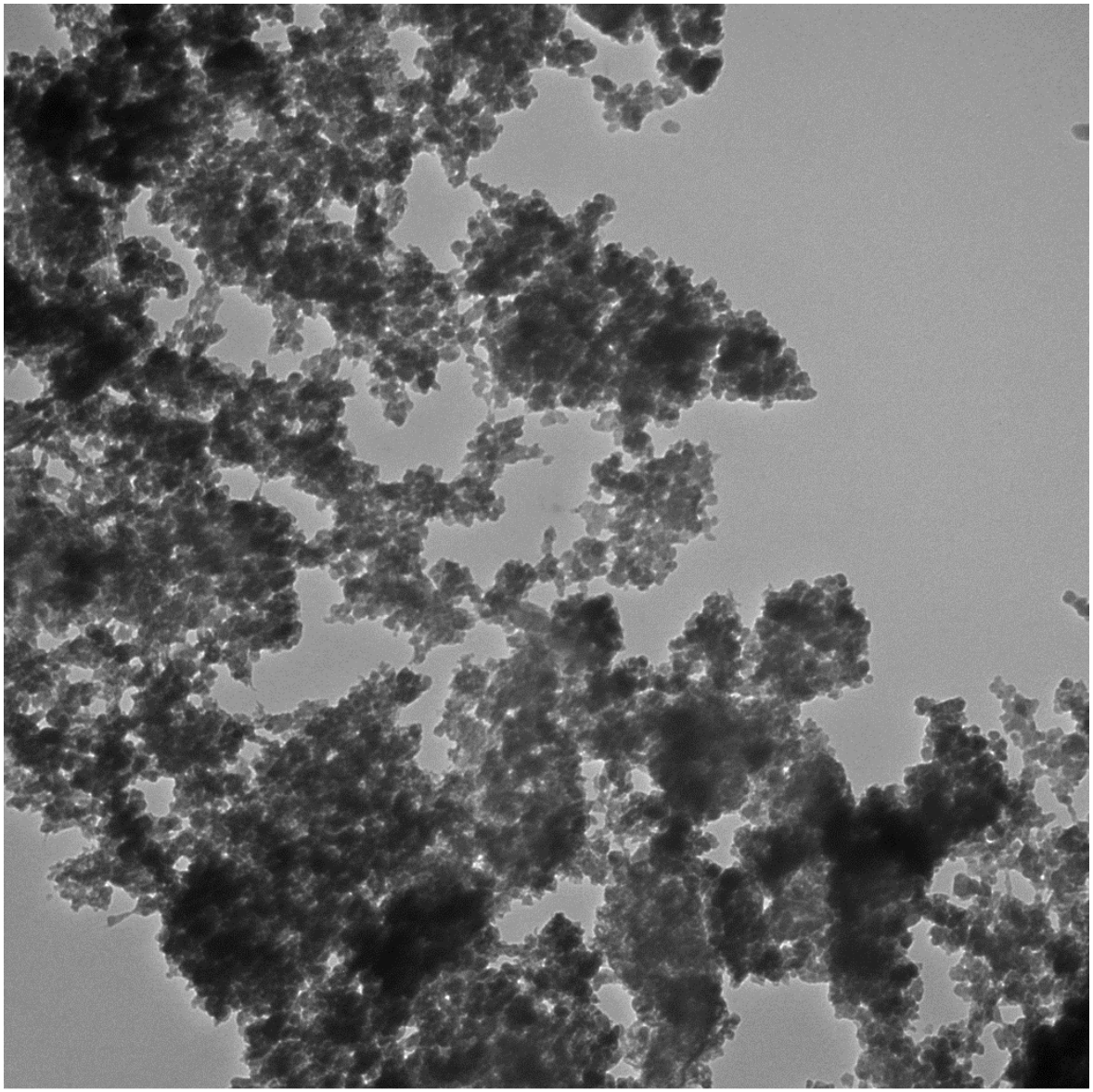




Uncoated mulch

WTR-coated mulch

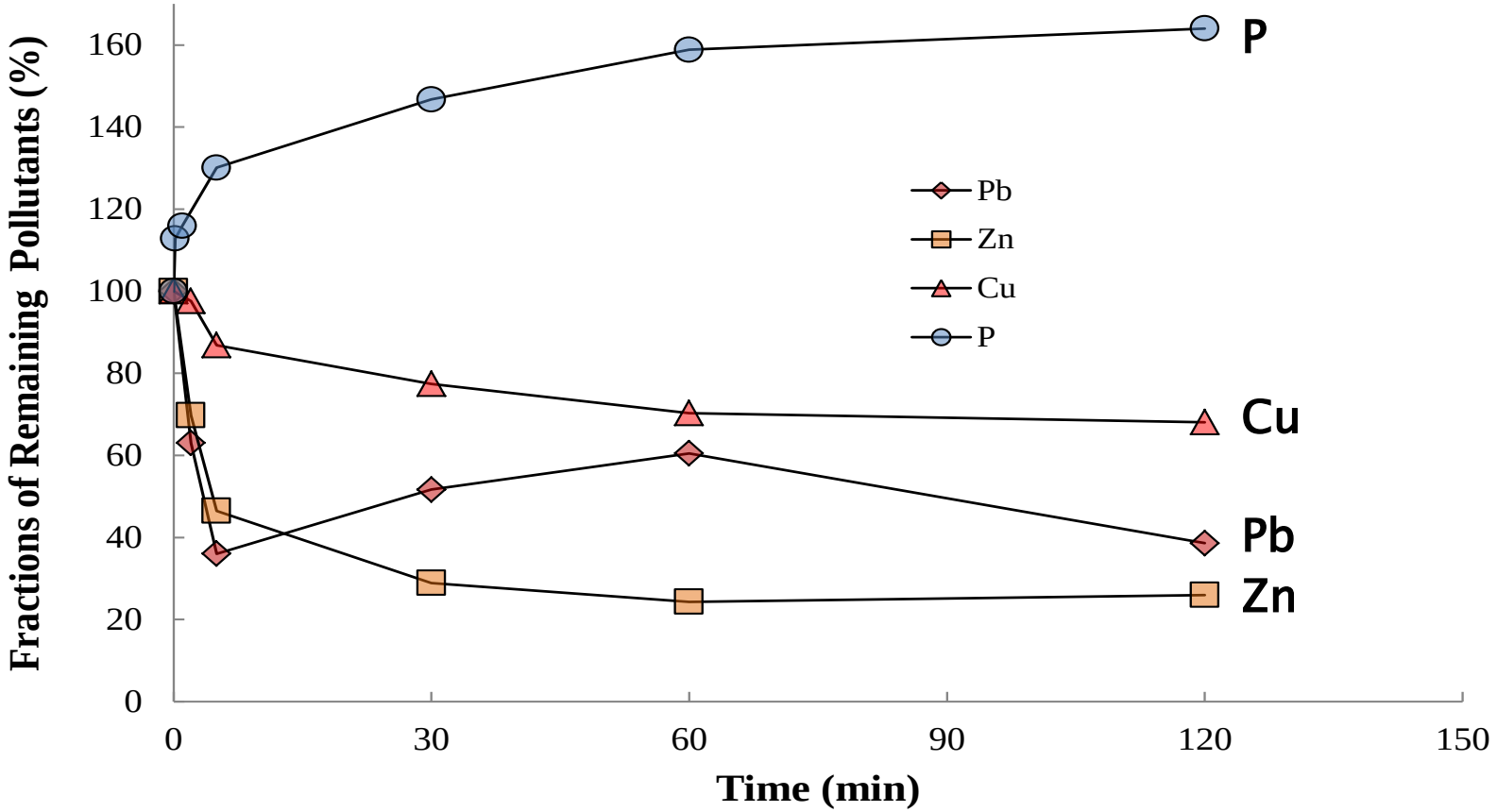
Micrographic images showing the presence of micro-size WTR particles.



Simulated urban runoff

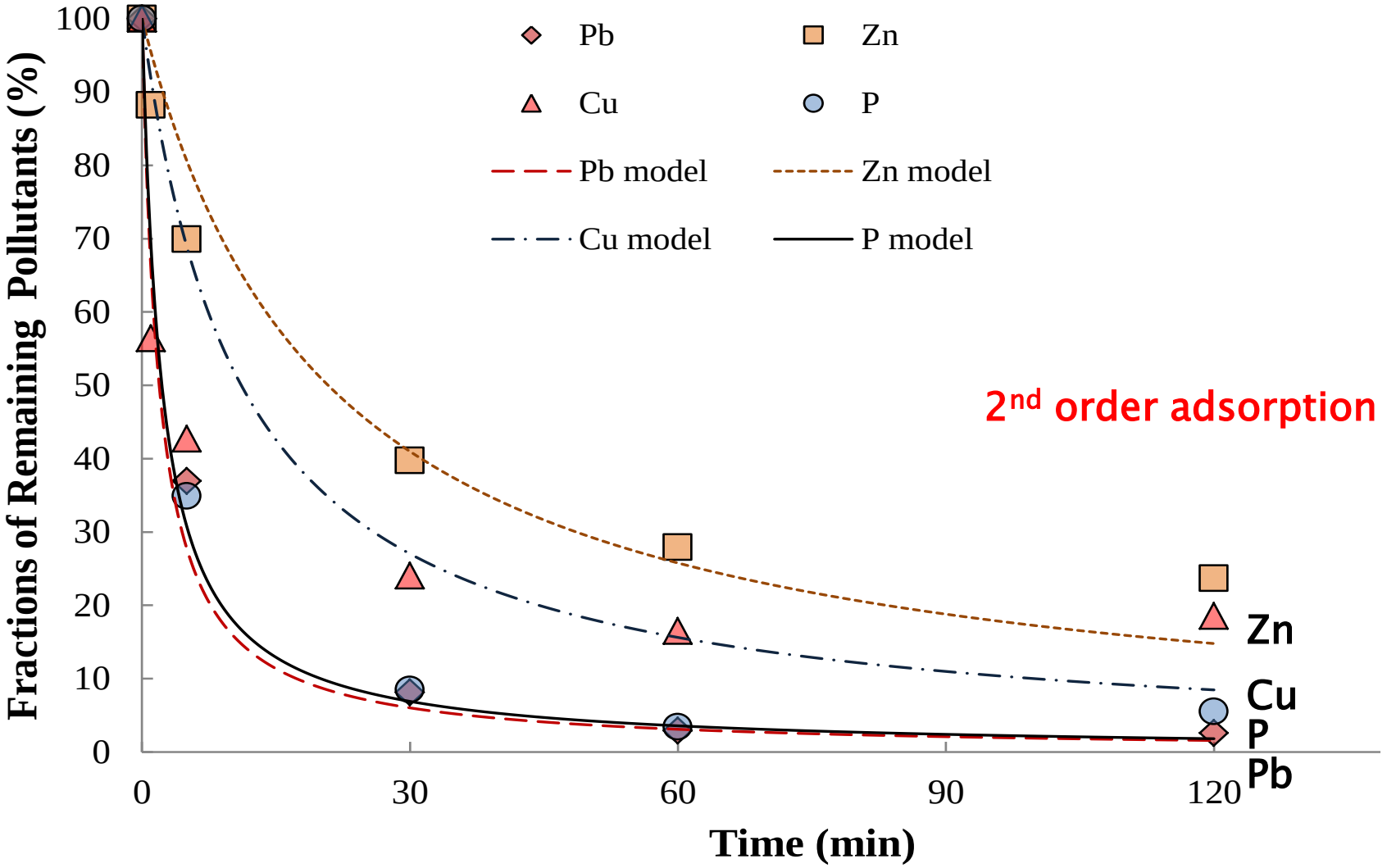
Parameter	Sources	Concentration (mg/L)
pH	NaOH / HNO_3	6.9
Cu	$Cu(NO_3)_2.2.5H_2O$	0.1
Zn	$Zn(NO_3)_2.6H_2O$	0.8
Pb	$Pb(NO_3)2$	0.1
P	Na_2HPO_4	2.3 (as P)
Total dissolved solids	$CaCl_2$	120
Piperazinediethane-sulfonic acid (PIPES) as a pH buffer	$C_8H_{18}N_2O_6S_2$	10 mM

Batch tests (Uncoated mulch)



(WTR = 10 g/L; pH = 7.0; initial concentrations: Cu = 100 μg/L, Zn = 800 μg/L, Pb = 100 μg/L, and TP = 2.30 mg/L; RSDs were less than 6.0%, not shown in the figure).

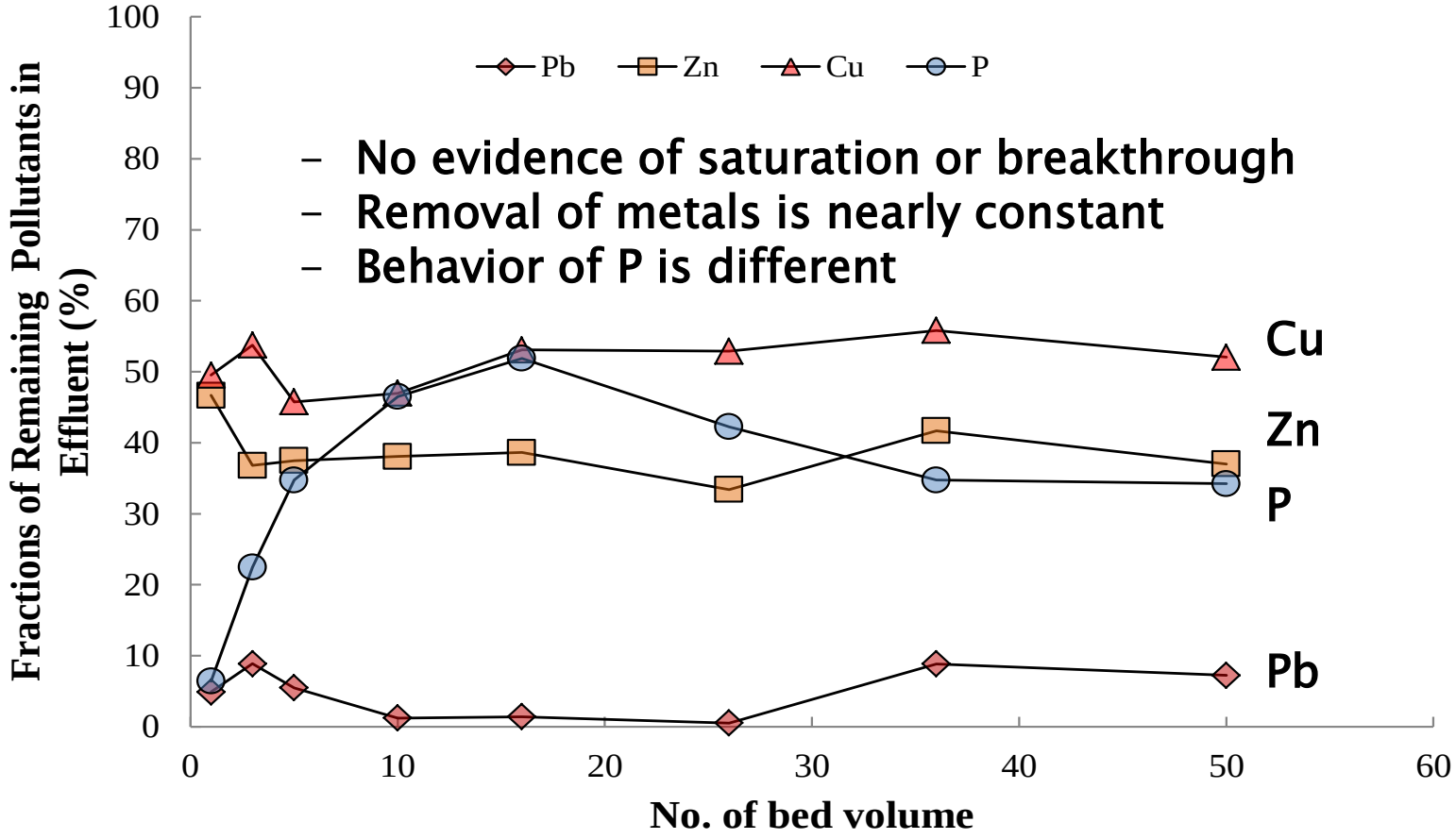
Batch tests (Al-WTR coated mulch)



(WTR = 10 g/L; pH = 7.0; initial concentrations: Cu = 100 μg/L, Zn = 800 μg/L, Pb = 100 μg/L, and TP = 2.30 mg/L; relative standard deviations were less than 6.0%, not shown in the figure).

Flow-through column tests: Column: 3 inch diameter, 2 inch of mulch/WTRs

Column tests (Al-WTR coated mulch)



(pH = 7.0; initial concentrations: Cu = 100 µg/L, Zn = 800 µg/L, Pb = 100 µg/L, and TP = 2.30 mg/L; RSDs were less than 6.0%, not shown in the figure).

Leaching tests

- Synthetic Precipitation Leaching Procedure (SPLP)
  - To evaluate the leaching potential of the used materials caused by rainfall.
  - US EPA standard Method 1311.

- Toxicity Characteristic Leaching Procedure (TCLP)
  - To evaluate the mobility of hazardous wastes in simulated landfill conditions.
  - US EPA standard Method 1312.

Leaching tests

	Contaminants (µg/L)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
SPLP Tests								
Unused mulch	0.022	1.972	10,230	3.295	29.330	2.015	2.043	0.000
Spent mulch	0.263	0.867	1,766	0.803	3.918	1.861	0.593	0.000
SPLP citerion[1]	800	3	120,000	80	N/A	40	100	800
TCLP Tests								
Unused much	0.030	2.977	3,603	2.408	47.290	4.287	7.513	0.000
Spent mulch	0.065	2.257	8,565	3.025	38.590	3.138	4.735	0.000
TCLP criterion[2]	5,000.0	5,000.0	100,000.0	1,000.0	5,000.0	200.0	1,000.0	5,000.0

[1]SPLP criterion: the higher of the health-based leachate criteria or aqueous practical quantitation levels (PQLs) when very little or no site specific information is available (NJDEP, 2013).

[2]TCLP criterion: maximum concentrations of contaminants for the toxic characteristics from 40 CFR 261.24 – Toxicity characteristic.

Conclusions

- Heavy metals and P were rapidly and effectively removed by WTR-coated mulch.
- WTR adsorption was a second order reaction with respect to each pollutant.
- Leaching of hazardous chemicals from spent WTR-coated mulch was insignificant.

Conclusions (cont.)

- WTR-coated mulch provides a new approach to reuse WTRs (an industrial waste).
- WTR-coated mulch is a new filter medium for alleviation of urban runoff pollutants.

Current Work to be completed in 2017

- Similar evaluation of Fe-based WTRs on mulch.
- Removal of oil.
- Effects of pH and temperature.

Future Work (contingent on funding)

- Field test of both Al and Fe based WTRs.

Acknowledgments

- Funded from Region 2 University Transportation Research Center (UTRC) and NJ Water Resources Research Institute.

- Dr. L. Wu (MSU) for SEM and TEM analysis.

- WTR was provided from NJ American Water.

- Dr. Virinder Sidhu and Hanieh Soleimanifar for chemical analytical work.


Question?